

FINAL REPORT

DESIGN VERIFICATION TESTING (DVT) FOR THE NEW CONTROL CABINET UNIT

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ABSTRACT

The overall objective of this project was the development of a control cabinet unit (CCU) that would be implemented in the future at U.S. airports by Federal Aviation Administration (FAA). This work included design, analysis, and testing of the control cabinet unit. The new control cabinet was designed by FIU-HCET and DME Corporation, using state-of-the-art components in order to eliminate expensive components and support the new lighting and remote monitoring system (RMS) requirements. These components include a micro controller with associated hardware and software support, solid-state relays for power distribution, miscellaneous components for remote and local control, and vacuum florescent display.

During the research and development process, the mechanical design and electrical circuit design and analysis were performed by FIU-HCET and DME Corporation team. After completion of the final mechanical and electrical design phase, DME Corporation developed two prototype control cabinet units. A series of Design Verification Tests (DVT) were conducted on the two prototype units. The DVT included electromagnetic interference testing (EMI), and Surge testing performed at *Rubicom Systems Inc. (RSI)* in Melbourne, Florida and environmental testing performed at East West Technology (EWT) in Jupiter, Florida and at Florida International University (FIU), in Miami, Florida. The DVT were conducted as per MIL-STD-461E and MIL-STD-810F for Navy and Air Force applications. This report summarizes the results of the design verification testing (DVT) of the CCU. Table 1 presents the summary of the DVT results.

Table 1 Summary of Design Verification Testing Results

Test Performed	Applicable Standard	Low cost control cabinet
1. Electromagnetic Interference Testing		
a. Conducted Emission	CE102 (10 KHz – 10 MHz)	Non-Compliant.
b. Radiated Emission	RE 102 (10KHz – 18 GHz)	Non-Compliant.
c. Radiated Susceptibility	RS103 (10 KHz – 40 GHz)	Compliant.
d. Conducted Susceptibility	CS114 (10 KHz- 400 MHz)	Compliant.
2. Surge Testing		
a. Surge	Method IEEE C62.45	Compliant.
3. Environmental Testing		
a. High Temperature	Method 501.4	Compliant, System operated.
b. Low Temperature	Method 502.4	Compliant, System operated; except #2 LED flasher light was out.
c. Humidity	Method 507.4	Complaint, System operated; except #2 flasher was out, current measured in L1 in high intensity mode was out of range.
d. Altitude	Method 500.4	Complaint, System operated.
e. Rain	Method 506.4	Complaint, System operated; except current measured in L2 in high intensity mode was out of range, small amount of water was found after bottom surface exposure.
f. Salt Spray	Method 509.4	Complaint, System operated; except rust formation at outside heat sink, and some LEDs flasher lights were out.
g. Sand and Dust	Method 510.4	Complaint, System operated.

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1.0 INTRODUCTION

The work conducted under this Co-Operative Agreement efforts focused on the development of a New Control Cabinet Unit (CCU) for the Federal Aviation Administration (FAA). This new CCU was designed to control airport approach lighting systems such as the halogen bar, sequence flasher lights, and other lighting systems that are present at airports' runway. The project included the electrical and mechanical design and analysis, the development of two prototype units (see Figure 1), and the design verification testing of the Control Cabinet Unit. The research team was integrated by Florida International University's Hemispheric Center for Environmental Technology (FIU-HCET) and DME Corporation.

Once the design and analysis phase was completed, DME Corporation developed two prototype units. FIU-HCET was responsible for developing the necessary DVT test plans, contracting Rubicom Systems Inc. and East West Technologies, and conducting three (3) environmental design verification tests. The Electromagnetic Interference (EMI) testing was conducted at Rubicom systems, Melbourne, Florida. Four environmental verification tests were conducted at East West Technology, Jupiter Florida. These test included the (altitude, rain, salt fog, sand & dust). The remaining design verification tests (low temperature, high temperature, and humidity) were conducted at Florida International University.

The purpose of the DVT was to validate the prototype of the CCU in accordance with military and industrial standards. In particular, the following were performed as per FAA and military standards (MIL-STD): Electromagnetic interference (EMI) testing (FAA-E-2325E & MIL-STD-461E), Surge testing (IEEE C62.41.2, IEEE C62.41.2, IEEE C62.45), and Environmental testing (MIL-STD-810F). The results from DVT are contained in this report.

2.0 EXPERIMENTAL

The DVT consisted of three distinct test areas. Test area I included the Electromagnetic interference testing (EMI). Test area II included a Surge Test. These tests were performed at Rubicom Systems, Inc., in Melbourne, Florida. Test area III included the environmental testing, which covered the following environmental conditions: high temperature, low temperature, humidity, altitude, rain, salt fog, and sand and dust. Temperature tests and humidity test were conducted at FIU and remaining tests were conducted at East West Technology Corporation, in Jupiter, Florida. The tests were conducted according to the following standards:

- Test method standard for measurement of EMI characteristics (FAA-E-2325E / MIL-STD-461E)
- IEEE Power Engineering Society IEEE Documents (IEEE C62.41.1 / IEEE C62.41.2 / IEEE C 62.45)
- Environmental engineering considerations and laboratory tests (MIL-STD-810F)

The control cabinet units were not only submitted to the above DVT as per military standards, but also during the DVT, the control cabinet units were submitted to a qualification test procedures developed and provide by DME Corporation (see Appendix 6.1).



Figure 1 Control Cabinet Prototype

2.1. Test Area I: Electromagnetic Interference Testing

Electromagnetic Compatibility (EMC) tests were conducted from February 14, 2005 to February 18, 2005 at Rubicom Systems, INC. located in Melbourne, Florida. For this EMI test the FAA-E-2325E standard was used. Four test methods with applicable requirements were identified to conduct the experiments based on MIL-STD-461E. These tests included:

1. CE102 – Conducted Emissions (CE), Power Leads, 10 KHz to 10 MHz
2. RE102 – Radiated Emissions (RE), 10 KHz to 18 GHz (tested from 200 KHz to 18 GHz)
3. RS103 – Radiated Susceptibility (RS), Electric Field, 10 KHz to 40 GHz (tested from 200 KHz to 18 GHz)
4. CS114 – Conducted Susceptibility (CS), 10 KHz to 400 MHz

CE102 Conducted Emissions Test

This method was used to confirm that electromagnetic emissions from the Control Cabinet Unit do not exceed the specified requirements for power input leads and returns. Test was conducted in the range of 10 KHz - 10MHz and the test procedure at medium intensity settings. Figure 2 depicts the setup used during this test.



Figure 2 CE102 Conducted Emission Compatibility Test Setup

CS114 Conducted Susceptibility Test

This method is used to confirm the ability of the Control Cabinet Unit to withstand RF signals coupled onto equipment under testing associated cabling. The test was conducted between the ranges of 10KHz - 400MHz and the test procedure at low intensity settings. Figure 3 depicts the setup used during this test.

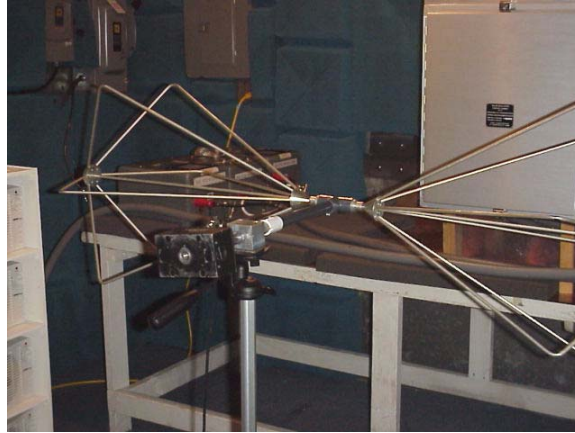


Figure 3 CS114 Conducted Susceptibility Compatibility Test Setup

RE102 Radiated Emissions Test

This test is used to confirm that electric field emissions from the Control Cabinet and its associated cabling do not exceed specified requirements. The test was conducted in the range of 10KHz - 18GHz and the test procedure at medium intensity settings. Figure 4 below depicts the setup used during this test.

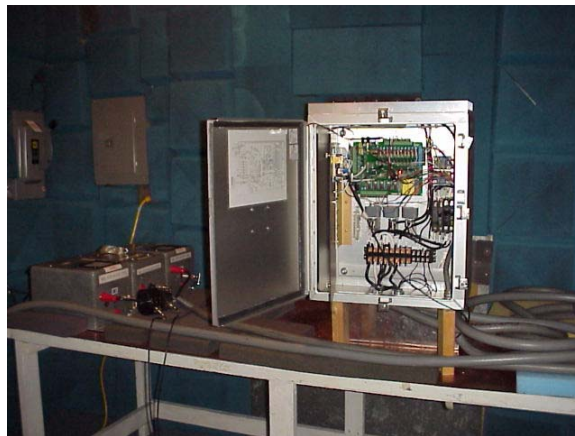


Figure 4 RE102 Radiated Emission Compatibility Test Setup

RS103 Radiated Susceptibility

This method is used to confirm the ability of the equipment under test and associated cabling to withstand electric fields. The test was conducted in the range of 10KHz - 40GHz and the test procedure at low intensity settings. Figure 5 depicts the setup used during this test.

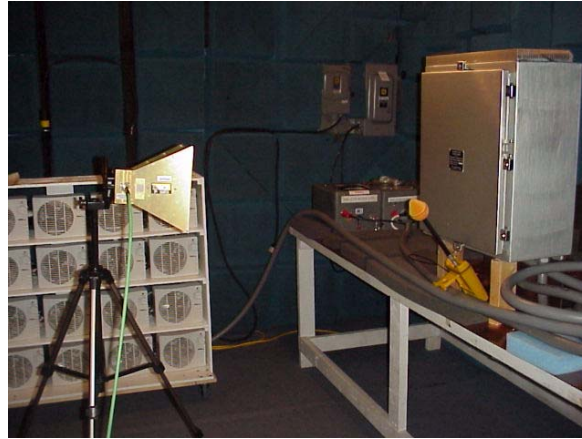


Figure 5 RS103 Radiated Susceptibility Compatibility Test Setup

2.2. Test Area II: Surge Test

The surge testing was performed on Low-voltage intensity. The test was focused on standard combination and 100-kHz ring waveforms to profile surge response characteristics. Figure 6 details the schematics for this test.

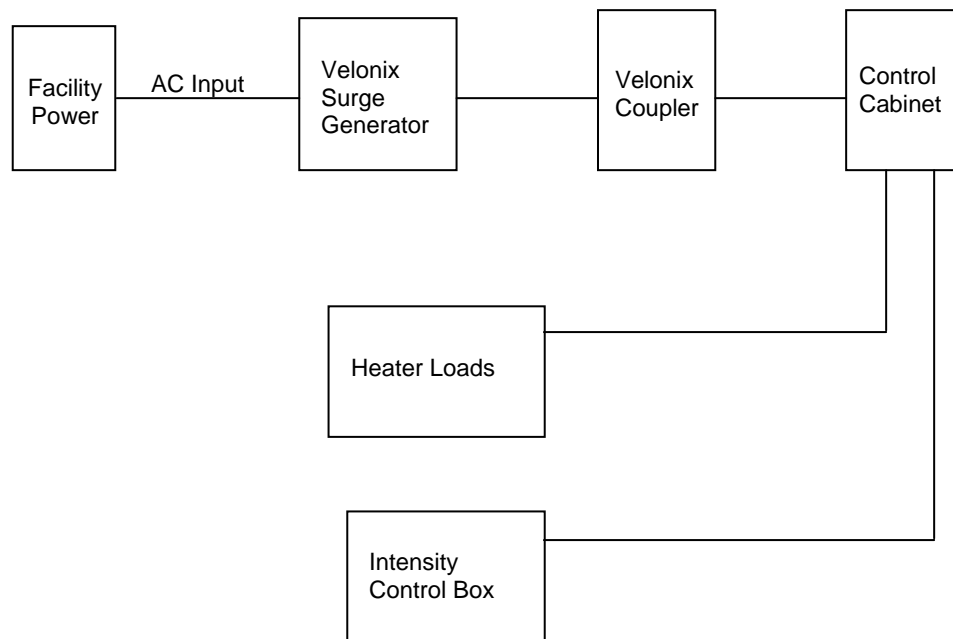


Figure 6 Surge Compatibility Test Setup

Two surge transients were applied to the primary input power. The first surge was the 1.5 μ sec/50 μ sec combination waveform. The second surge was the 100-kHz ring-wave. The combination waveform was injected with 12ohm source impedance. The ring-wave was injected using the 30ohm source impedance. Each waveform was applied 5 times in positive and negative polarities. Both were tested up to 6kV.

2.3.Test Area III: Environmental Testing

Environmental testing was conducted in two phases. Phase1 consisted of high temperature, low temperature, and humidity test. These tests were conducted at FIU facility, starting on March 10, 2005 and ending on March 28, 2005. Phase 2 consisted of altitude test, rain test, salt fog test and sand/dust test. These tests were conducted at East West Technology Corporation, starting on March 01, 2005 and ending on March 14, 2005. All environmental tests were conducted as per MIL-STD-810F. Table 2 shows the type of test and the section of the standard used, according to MIL-STD-810F.

Table 2 Environmental Test Methods followed according to MIL-STD-810F

Test No.	Test Condition	Section
1	High Temperature	Method 501.4
2	Low Temperature	Method 502.4
3	Humidity	Method 507.4
4	Altitude	Method 500.4
5	Rain	Method 506.4
6	Salt fog	Method 509.4
7	Sand and Dust	Method 510.4

High Temperature

The test started with a visual inspection of the CCU system and then continued with exposing the unit to cycling high temperatures to a maximum of +70 °C exposure. During the test, three “remote mode” operational checkout tests within each cycle were conducted according to DME qualification test procedures (see Appendix 6.1). For detailed procedures of the experiment, refer to Appendix 6.2 High Temperature, Low Temperature and Humidity Tests Performance for the Control Cabinet Unit.

Equipment used

The equipment/instruments used for this test were the following

- Thermotron temperature chamber (29” x 29” x 29”)
- Thermocouples (8)
- Data Acquisition system
- Amp probe
- Digital oscilloscope
- Desktop computer

Low temperature

The test started with a visual inspection of the CCU system, then continued with the exposing the unit to cycling low temperatures to a minimum of -40 °C exposure. During the test, three “remote mode” operational checkout tests within each cycle were conducted according to DME qualification test procedure (see Appendix 6.1). For

detailed procedures of the experiment, refer to Appendix 6.2 High Temperature, Low Temperature and Humidity Tests Performance for the Control Cabinet Unit.

Equipment used

The equipment/instruments used for this test were the same as in the High temperature test.

Humidity

The test started with a visual inspection of the CCU system, and then continued with exposing the unit to 5 temperature/humidity (95% RH +20 °C to + 60 °C) cycles with 48 hours period each. During the test, two “remote mode” operational checkout tests within each cycle were conducted according to DME qualification test procedure. For detailed procedures of the experiment, refer to Appendix 6.2 High Temperature, Low Temperature and Humidity Tests Performance for the Control Cabinet Unit.

Equipment used

The equipment/instruments used for this test were the same as in the High and Low temperature tests.

Altitude (Low pressure)

The test started with a visual inspection of the CCU system, then continued with exposing the unit to low pressure 20.56” Hg to simulate 10,000 feet altitude. During the test, a “remote mode” operational checkout test was conducted according to DME qualification test procedures. For detailed procedures of the experiment, refer to Appendix 6.3 East West Report.

Equipment used

- Test Chamber (4’ x 4’ x 4’)
- Transducer
- Three Data Acquisition Boards (CIO DAS 802/16, CIO EXP 32, CIO DAC 08)

Rain

The test started with a visual inspection of the CCU system, then continued with exposing the unit to simulated rain of 4 in/hr and with a simulated wind of 41 mph. During the test, a “remote mode” operational checkout test for each side of the cabinet was conducted according to DME qualification test procedures. For detailed procedures of the experiment, refer to Appendix 6.3 East West Report.

Equipment used

- Wind Machine
- Wind speed Indicator
- Stop Watch
- Pressure Gauge

- Rain Gauge

Salt Fog

The test started with a visual inspection of the CCU system, preparation of the salt solution, and determination of the fallout rate, and then continued with exposing the unit to 48 hours of salt fog. After the test, an operational checkout test was conducted according to DME qualification test procedures. For detailed procedures of the experiment, refer to Appendix 6.3 East West Report.

Equipment used

The instruments used for this test were the following:

- Test Chamber (3' x 3' x 4')
- Two Temperature controller
- Chart recorder
- Hydrometer
- PH Meter

Sand and Dust

The test started with a visual inspection of the CCU system, and then continued with exposing the unit to 6-hour cycles of blown dust at each axis. At the end of the last cycle, an operational checkout test was performed according to DME qualification test procedures. Then the system was exposed to 6 cycles of blown sand. For detailed procedures of the experiment, refer to Appendix 6.3 East West Report.

Equipment Used

The instruments used for this test were the following:

- Test Chamber (6' x 6' x 6')
- Dust Density Gauge
- Three Data Acquisition Boards
- RH Probe
- Stop Watch
- Wind Meter
- Temperature Controller
- Chart Recorder
- Digital Volt Meter

3.0 RESULTS AND DISCUSSIONS

The results for all Design Verification Tests are presented in a summary form in the following section. Detailed results are presented in Appendices 6.2, 6.3, and 6.4 were copies of FIU-HCET's "High Temperature, Low Temperature and Humidity Tests Performance for the Control Cabinet Unit," East West Technology Report, and Rubicom Systems Inc. "Electromagnetic Interference Test Report" are presented.

3.1. Test Area I: Electromagnetic Interference Testing

The electromagnetic compatibility testing was performed during the month of March at Rubicom Systems of Melbourne Florida. The tests performed were Conducted Emissions (CE 102), Radiated Emission (RE 102-4), Conducted Susceptibility (CS114) and Radiated Susceptibility (RS 103), in that order. The system performed well in all the susceptibility testing with no failures of operation throughout the testing procedures. For the emissions testing, the system failed both tests performed. For radiated emissions, the system exceeded the standard's threshold emissions at 2-4 MHz and 96-98 MHz while on the "medium" intensity setting. Additional tests performed at "low" intensity also showed the system failing the standard. For conducted emissions, the system was above the standard's limits for the entire frequency range.

After completion of the testing, FIU and DME discussed the results and it was determined that the radiated emissions should be repeated, due to the presence of the heater loads inside the test chamber. Three weeks later, the system was re-tested at Rubicom systems for radiated emissions. The system was tested at the failure bands, and continued to exceed the standard limits. Rubicom, DME and FIU representatives, on-site, attempted to decrease the emissions by adding aluminum foil to the cabinet's seal to remove any emission outlets. This reduced the energy being emitted, but the result still exceeded the standard. Probing the system for individual spots of emission showed that the emissions were coming from the output of the solid-state relays. This was discussed between FIU and DME representatives and was determined to be a problem that could not be field corrected, so the tests were completed in the system's current state. For detailed test results refer to Appendix 6.4, Electromagnetic Interference Test Report.

3.2. Test Area II: Surge Test

The Control Cabinet did not exhibit any degradation during injection of the combination waveform or ring-wave. For detailed test results refer to Appendix 6.4, Electromagnetic Interference Test Report.

3.3. Test Area III: Environmental Testing

For the environmental testing, HCET developed a sequence of test conditions and test specifications, as listed in Table 2, of the Experimental Section. Detailed results, tables, and graphs of the information collected during the tests are presented in Appendix 6.2,

High Temperature, Low Temperature and Humidity Tests Performance for the Control Cabinet Unit and Appendix 6.3, East West Technology Test Report.

High Temperature

The CCU system operated at high intensity during the high temperature exposure test, although temperatures above +70 °C were found in some of the components. After the exposure, visual examination did not reveal any indication of damage. Figure 7 presents the interior components of the control cabinet after exposure.



Figure 7 Cabinet unit after the High Temperature Exposure

Low Temperature

The CCU system operated at low intensity during the entire low temperature exposure, although one sequential flasher LED light did not work in the last cycle of the 3 cycle test. An oscilloscope was also used to measure the pulse under each one of the working intensities of the CCU, since the oscilloscope measured a pulse it was concluded that the CCU was working as intended. After the exposure, visual examination did not reveal any indication of damage, some moisture and frost was found due to the low temperature. Figure 8 shows some of the moisture and frost detected after the test.



Figure 8 Picture displaying Droplets formed during the Low Temperature Exposure

Humidity

The CCU system operated during the entire humidity exposure, although one sequential flasher LED light did not work during all the 5 cycles of the test. Pulse was measured using an oscilloscope and it was determined that the flashing LED light was out. After the exposure, visual examination did not reveal any indication of damage (see Fig. 9).

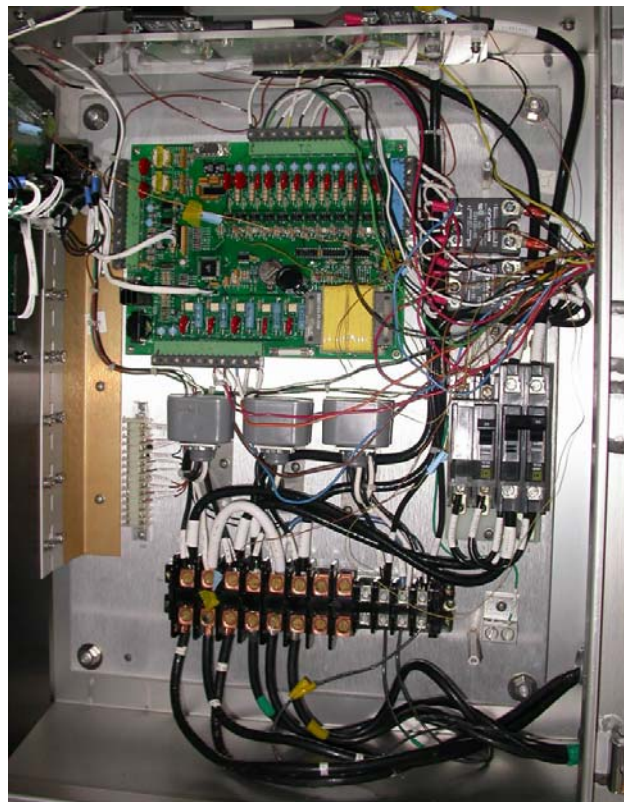


Figure 9 Control Cabinet Unit after Humidity Exposure

Altitude

The CCU system operated during the altitude (Low pressure) test. After the exposure, visual examination did not reveal any indication of damage. Figure 10 shows the system after the test.

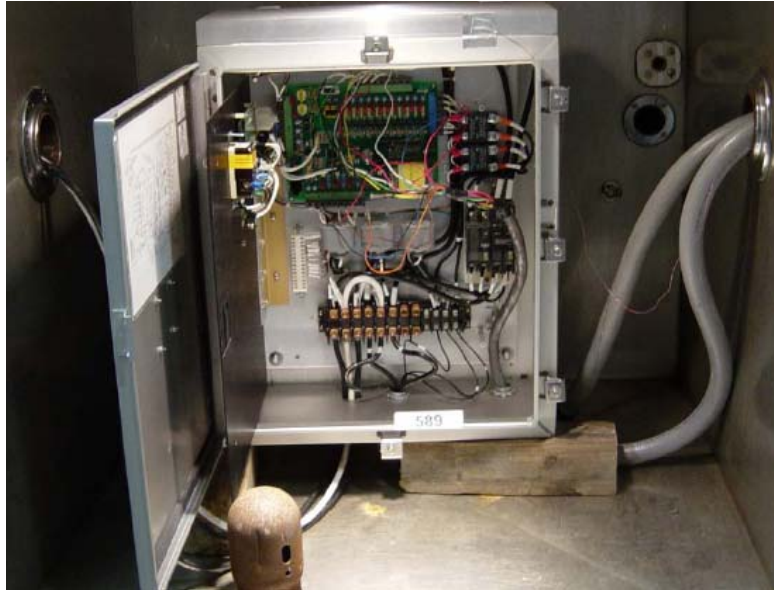


Figure 10 Cabinet Unit after the Altitude test

Rain

The CCU system operated during the entire rain exposure, although the current measured in L2 when operated in “remote mode” and “local mode” was in the range specified by DME. After the exposure, a visual examination did not reveal any indication of damage. Figure 11 shows the system during the rain exposure.



Figure 11 Picture displaying the Cabinet unit after Rain Exposure

Only a small amount of water was detected during the rain exposure to the bottom surface of the cabinet unit. It is believed that water penetrated the cabinet through the compression fitting and seals. This was due to the excessive number of times that the fitting and seals were removed during the setup and breakdown of the electrical connections to the cabinet unit. This is an unlikely situation since the cabinet units are installed in an upright position and cables come through the bottom of the cabinet, it is extremely unlikely that this surface will be exposed to rain.

Salt Fog

The CCU system operated during the exposure, although some of the sequential flasher LED's did not work. After the exposure, rust was noted on the top of the test unit next to heat sink and some salt trails on all sides and corrosion on conduit was observed during the visual inspection. Figure 12 shows the cabinet after salt test exposure.



Figure 12 Control Cabinet Unit after Salt Exposure

Sand and Dust

The CCU system operated during the exposure to sand and dust. After the exposure, visual examination did not reveal any indication of damage. Figure 13 show two pictures of the cabinet after Sand and Dust exposure test.



Figure 13 Pictures Displaying Cabinet unit after Sand and Dust Exposure

4.0 CONCLUSIONS

The Design Verification Testing for the Control Cabinet was conducted throughout the month of March 2005. Table 3 present the summaries of DVT testing results for the control cabinet unit.

Table 3 Summary of Design Verification Testing Performance of CCU

Test Performed	Applicable Standard	Low cost control cabinet
1. Electromagnetic Interference Testing		
a. Conducted Emission	CE102 (10 KHz – 10 MHz)	Non-Compliant.
b. Radiated Emission	RE 102 (10KHz – 18 GHz)	Non-Compliant.
c. Radiated Susceptibility	RS103 (10 KHz – 40 GHz)	Compliant.
d. Conducted Susceptibility	CS114 (10 KHz- 400 MHz)	Compliant.
2. Surge Testing		
a. Surge	Method IEEE C62.45	Compliant.
3. Environmental Testing		
a. High Temperature	Method 501.4	Compliant, System operated.
b. Low Temperature	Method 502.4	Compliant, System operated; except #2 LED flasher light was out.
c. Humidity	Method 507.4	Complaint, System operated; except #2 flasher was out, current measured in L1 in high intensity mode was out of range.
d. Altitude	Method 500.4	Complaint, System operated.
e. Rain	Method 506.4	Complaint, System operated; except current measured in L2 in high intensity mode was out of range, small amount of water was found after bottom surface exposure.
f. Salt Spray	Method 509.4	Complaint, System operated; except rust formation at outside heat sink, and some LEDs flasher light were out.
g. Sand and Dust	Method 510.4	Complaint, System operated.

4.1.Test Area I: Electromagnetic Interference Testing

The control cabinet unit prototype did not comply with Conducted emissions (CE102) and Radiated Emissions (RE102) standards. The control cabinet unit did comply with Radiated Susceptibility (RS103) and Conducted Susceptibility (CS 114) standards. Due to the theory of operation, the system is prone to generating excess EM emissions during low and medium intensity operations. It has been determine that the need for line filtering and shielding is required to ensure the system will meet the MIL specifications in the future. Additional work in this area is currently being performed at DME Corporation.

4.2.Test Area II: Surge Testing

The system was designed and rated to perform in accordance with the IEEE surge specifications.

4.3.Test Area III: Environmental Testing

The Environmental testing was conducted on the control cabinet unit. The system operated successfully during the High Temperature, Low Temperature, Humidity, Altitude, Rain, Sand and Dust and Salt Fog tests. As detailed in Appendix 6.2, DME had equipped the two prototype control cabinet units with a trigger box for remote operation of the CCU during the various design verification tests. This trigger box controlled the three intensities of the CCU and physically showed (by using LED lights) the flashing sequence operation of the CCU. During the Low temperature, Humidity, and Salt Fog exposure, however, one of the LED light on the hand trigger box went out and the light did not flashed as intended. During the FIU-HCET tests an oscilloscope was installed to monitor for the pulse generated for each intensity. Pulses were measured and recorded for the entire tests performed at FIU-HCET. Based on this information it was concluded that the failure was due to the LED light malfunctioning.

DME provided a “heater bank load” unit for each prototype to simulate the load to the cabinet due to steady burning lights. This “heater loads” were composed of 20 heater fans, each providing 1.5 KW for a total of 30 KW of resisting load. The fans were balance to provide a pre-determine current range for each intensity. For low intensity the current range was 20 -22 amps, for medium intensity the current range was 38-44 amps, and for high intensity the range was 58-62 amps. During the DVT the range of currents (amps) for each intensity was measure and recorded by using an amp-probe (Leg L1 and Leg L2. Refer to appendices 6.2 and 6.3, for the data sheets collected during the tests. During Rain and Humidity exposure, the current measured in high intensity mode was not in the range specified by DME. It was determined that the non-compliance was due to failure of one or more fans of the heater bank load breaking down.

5.0 RECOMMENDATIONS

From an electrical design standpoint, This R&D prototype provides several improvements over the current MALRS control cabinet. The system does not require the amount of mechanical contactors used in the current system, limiting failures and chatters associated with such components. Also, the use a microcontroller provides versatility for future improvement; a feature not available on the current system. Overall, this prototype shows promise as the new generation of runway lighting system control cabinets.

Due to the results of the EMI emissions testing, the system still requires several improvements to reach a design meeting all the FAA requirements. In order to reach this stage, it is recommended that after several design modifications, the system undergo long-term reliability testing to determine the viability of this alternative versus the current. Additional recommendation would be collaboration between EMI specialists, SSR manufacturer and the project team to develop a SSR that would ensure compliance with the performance standards.

From the environmental testing point of view, the cabinet performed as expected, only a small amount of water was detected during the rain exposure to the bottom surface of the cabinet unit. It is believe that water penetrated the cabinet through the compression fitting and seals. This was due to the excessive number of times that the fitting and seals were removed during the setup and breakdown for each environmental test. This is an unlikely situation since the cabinet units are installed in an upright position and cables come through the bottom of the cabinet, it is extremely unlikely that this surface will be exposed to rain. It is recommended that for future DVT test, a 4 ft long “pig tail” connection is provided so that connection are made outside the cabinet without having to connect and disconnect the cables.

REFERENCE

Test Plan/Procedure for the Design Verification Test for the Control Cabinet Unit. HCET, FIU, February 2005.

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MIL-STD-810F Environmental Engineering Considerations and Laboratory Tests, Department of Defense Test Method Standards, January 2000.

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High Temperature, Low Temperature and Humidity Tests Performance for the Control Cabinet Unit, Florida International University-HCET, May 2005.

6.0 APPENDICES

6.1.Appendix

DME Qualification Test Procedure

6.2.Appendix

**High Temperature, Low Temperature and Humidity Tests Performance for the
Control Cabinet Unit**

6.3.Appendix

East West Report

6.4.Appendix

Electromagnetic Interference Testing Report